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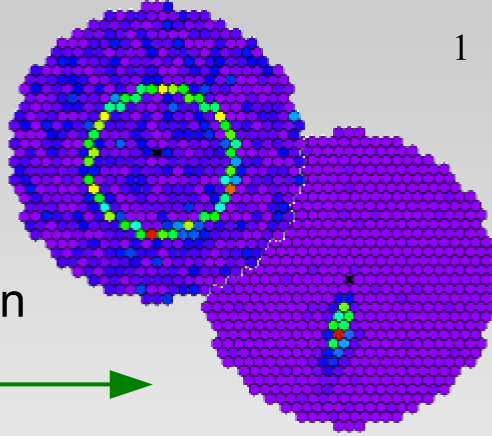
Camera Electronics and REflector Simulation



What questions should the simulations answer?

- Pulse shape
- Gain
- Sampling frequency
- Pixel size (granularity, number of APDs per pixel, ...)
- Pixel number (Camera size, Wobble mode, ...)
- Trigger layout (Sum, 3NN, ...)
- Needed timing accuracy
- Calibration (how to calibrate the gain, ...)

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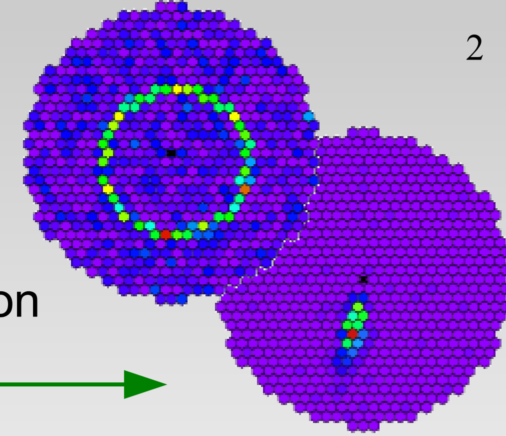
Camera **E**lectronics and **RE**flector **S**imulation



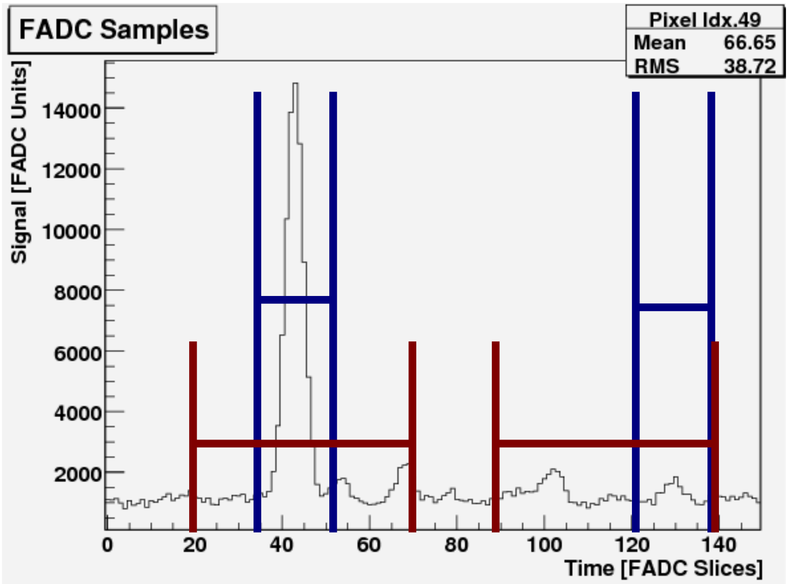
Pulse shape

- The smaller the pulse the less night sky noise (NSB) we integrate
  - It is not clear whether this makes a difference because the more important *source* of noise it the search window not the integration window.

- Small pulses need faster sampling (more data to be transfered)
- Smaller pulses reduce the probability of high overlapping pulses from NSB!
  - ➔ For the trigger short, but not too short, and high pulses might be better (note that also gammas have a time-slope along their axis)

- If pulses are small and undershoot they might attenuate the short gamma-signals (short time between two photons O(ns))
- If pulses are wider and undershoot they might attenuate the long hadron-signals (longer time between two photons O(few ns))

- Apart from NSB
  - Fast rise times might help to extract the *timing* more accurately



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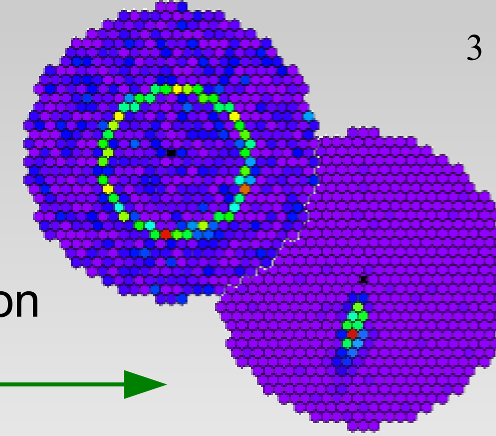

Gain

- Therefore we should check the number of *saturating* pixels per event.
- Where do we loose more:
  - None resolution of the small signals
  - Underestimation of the highest signals

- Loosing high signals is a drawback for a few extremely bright showers
  - But at high energies we are mainly limited by the signal rate!
  - Our monitoring program is ideal to resolve these energies.
  - On the other hand we might *reconstruct* lost charge knowing the response of the electronics

- Loosing precision at low energies might directly influence our background suppression, because of worse spatial resolution but maybe also worse time resolution.
  Thus influences directly our threshold and consequently our sensitivity

- We should simply simulate what signals (APD response) we expect from which energy range

- My current *best guess* is: 5 for a single photon, the maximum for 300-1000.

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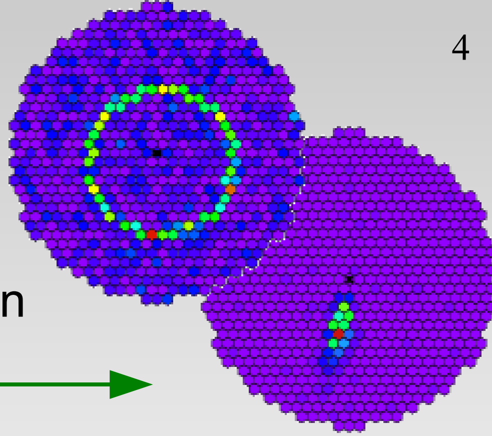
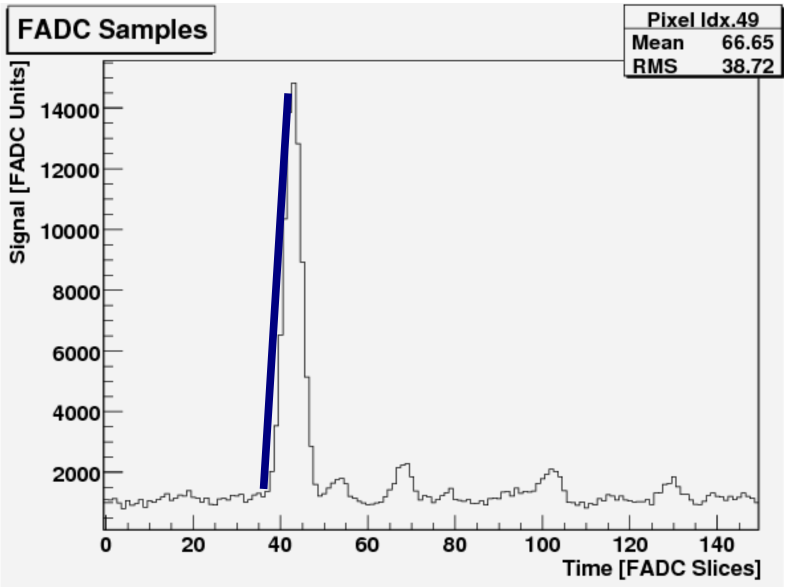


Sampling frequency and timing accuracy

- Theory says that a sampling twice as fast as the smallest signal you want to resolve is enough
- The smallest *signal* we (currently) want to resolve is the rising edge of the pulse
- Assuming an ideal rise time of 0.5ns in the order of the shortest arrival time difference between photons (for muons it is less than 0.5ns) and a safety margin we should sample with ~5 points per nanosecond: 5GHz
- If the pulse rise time is slower we can reduce sampling speed accordingly
- The timing accuracy should be good compared to the time we want to resolve. Assuming we want to resolve times in the order of 0.5ns the timing accuracy should be at least 0.5ns / $\sqrt{2}$
(This value does not directly depend on the rise time of the pulse!)



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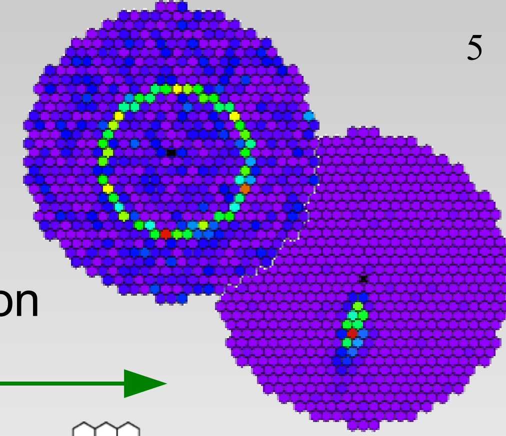
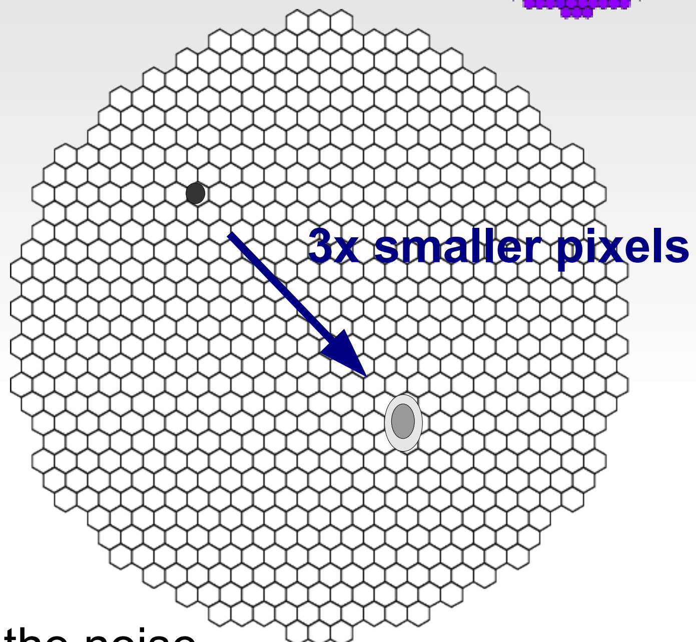


Pixel size



- The pixel size defines the
  - Signal-to-noise ratio
  - Light yield

- What are the constraints?
  - Large pixels:
    - Small showers cannot be resolved (size!)
    - Dim showers have a better signal-to-noise ratio
  - Small pixels:
    - Small showers can be resolved
    - But the signal might not be bright enough to be over the noise
    - Does it make sense to have pixels smaller than the average spatial distance between two photons?

- Note, that this effect depends highly on the signal reconstruction:
  - We can sum pixels in the analysis even for a clever image cleaning
  - We can use signal timing in the cleaning or also for extraction (don't search everywhere but only around a position where neighbors have a signal)
    - ➔ We might be able to reduce the noise further.

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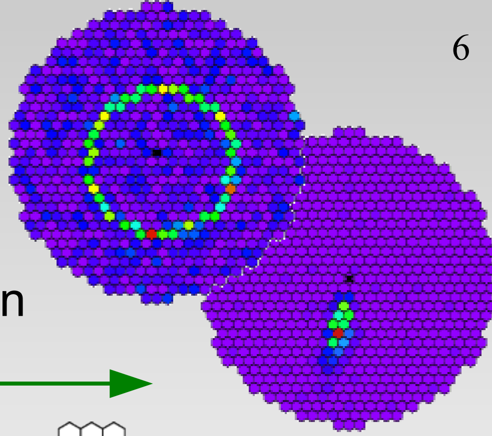
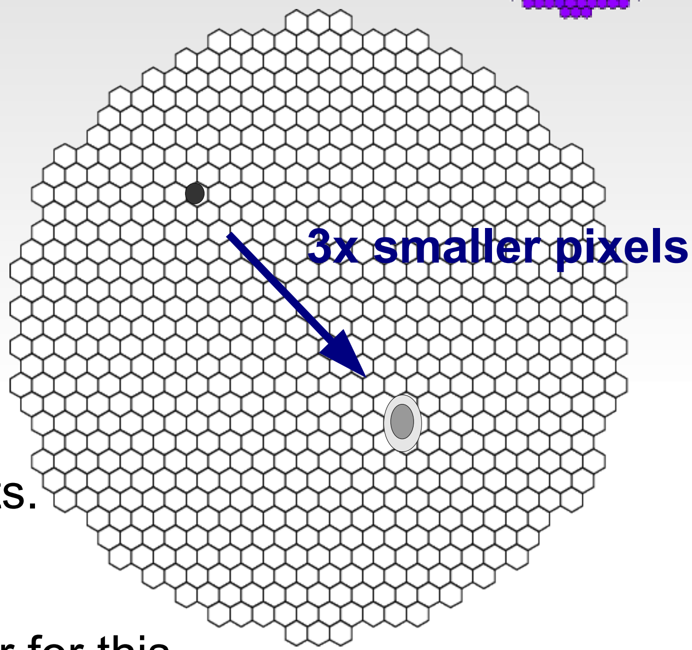


Camera **E**lectronics and **RE**flector **S**imulation

Pixel size



- Difficult to do a study on this because the result depends on
  - The trigger
  - The signal reconstruction (image cleaning + parameters)
  - The image reconstruction

- The trigger:
  - Can be made *similar* for smaller pixels (sum before discriminator) so that we trigger more or less the same events.
  - So we can only win with smaller pixels
  - Since our threshold will be determined mainly by the signal-reconstruction (cleaning) we might just use an artificial trigger for this.
    - ➡ First optimize pixel size, then optimize the trigger

- Signal reconstruction:
  - Can we scale the cleaning threshold with the square root of the pixel area?
  - Should we keep the cleaning at the same level?
  - Should we use time constraints?
  - It would be hard to optimize the cleaning without reasonable background and optimizing the full reconstruction chain (disp, area-cut, etc)

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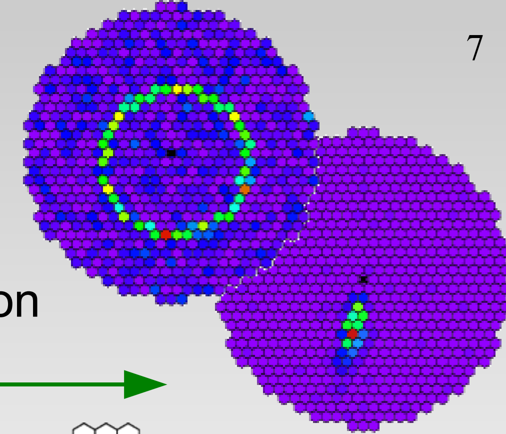
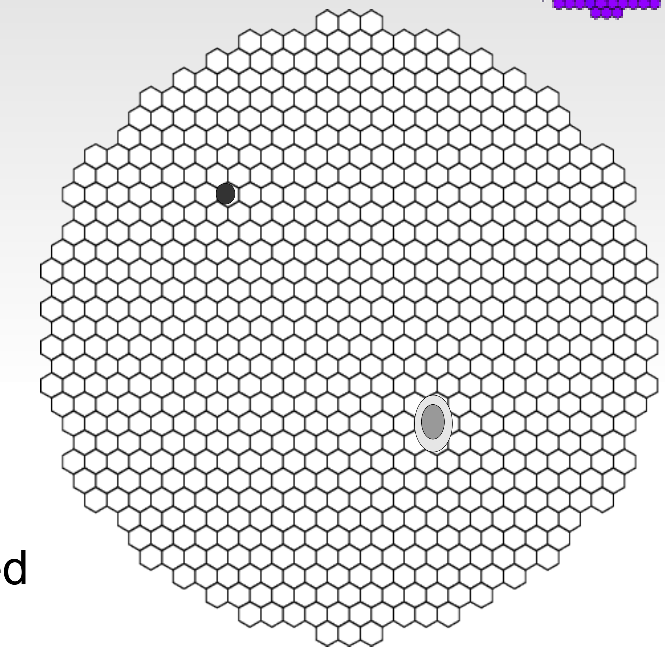
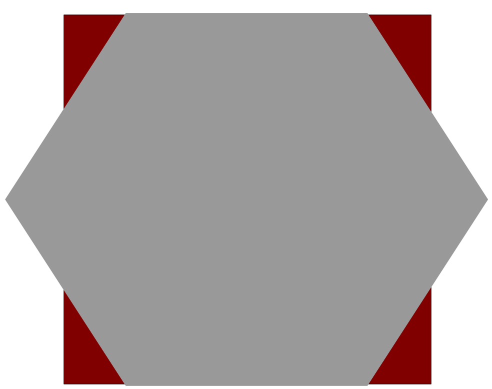




Pixel shape

- The center-of-gravity of all pixels should be ordered in a hexagonal arrangement to ensure that the average distance (time) to their neighbors is always the same.
  - This is possible for 1, 2, 3, 4, 5, (6?) and 7 APD-pixels
  - Geometrically 1, 3 and 7 is the most symmetric
- The individual pixel shape doesn't matter much, the difference is just too small although hexagonal is preffered



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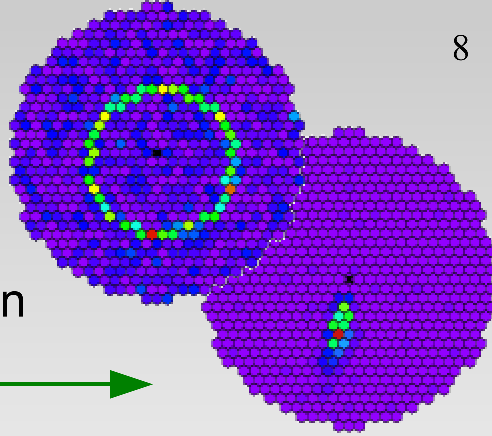

Camera size

- To take data in wobble mode with a distance allowing for at least 5 off-regions (for symmetry reasons), the camera must be large enough:
  - This is no problem for the low-energy showers, but TeV (low TeV region) are bright enough that they easily reach out of the camera if they have a large impact parameter. Therefore a larger camera should give a better collection area for high-energy showers
    → the only way to increase the sensitivity at high energies

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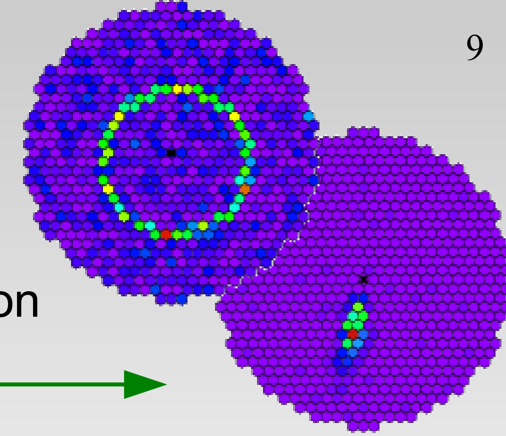

Trigger layout

- The main goal of the trigger is robustness and homogneity
  - Therefore it might make sense to reduce the number of discriminators
  - The sum-trigger concept seems reasonable
  - After we have optimized the camera layout to give the best threshold after reconstruction (cleaning?) we have to optimize the trigger to trigger all events which will later be reconstructed.
  - We could use the timing (length of the signals) in the trigger... (robust?) Especially for sum-trigger it might be worth to investigate this..?

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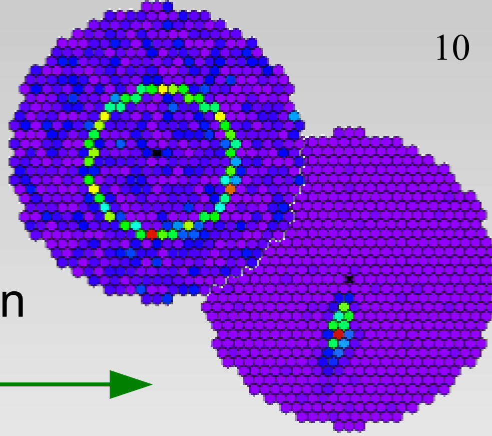
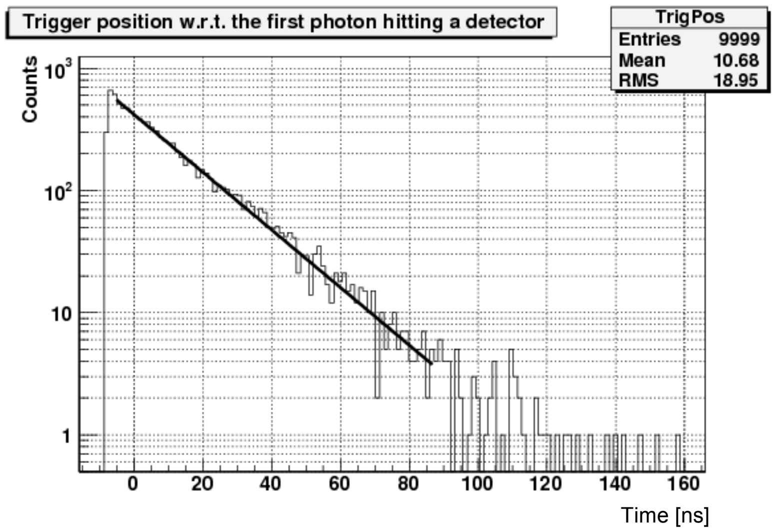


Trigger layout

- How can we optimize the trigger?

  - Produce pedestal (NSB) events.
  - Lower the threshold until they start to trigger
  - For the distribution of the time difference between the artificial start point of our simulation and the trigger we should find an exponential distribution
    ➨We can calculate the trigger rate of accidentals (in analogy to fitting the eff. on-time)



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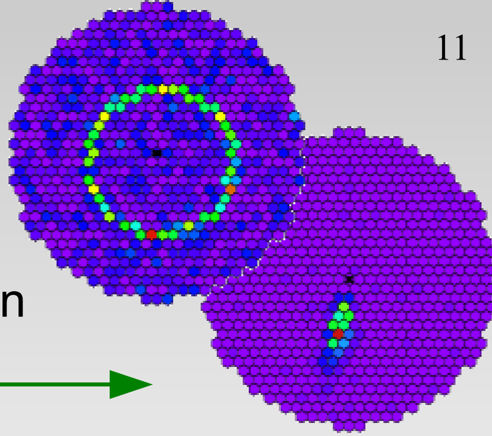
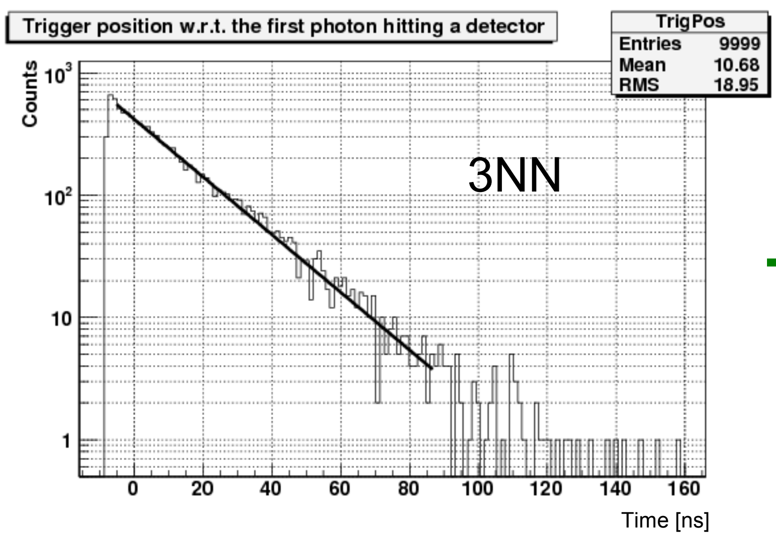
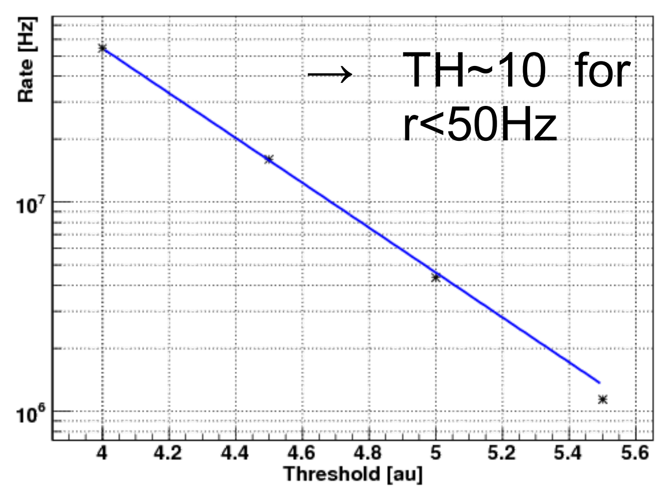


Trigger layout

- Doing this for different thresholds we can plot rate-vs-threshold and determine the threshold at which the rate falls well below the expected trigger rate from real shower (This rate is expected to be <<50Hz, roughly two orders of magnitude less than for MAGIC (500Hz@E_γ=50GeV), because we trigger ~one order of magnitude higher in energy and the hadron background has a slope of -2.7, no matter at which hadron energy our threshold is)

- This would be the easiest to be done semi-automatic (condor_dag, database?)





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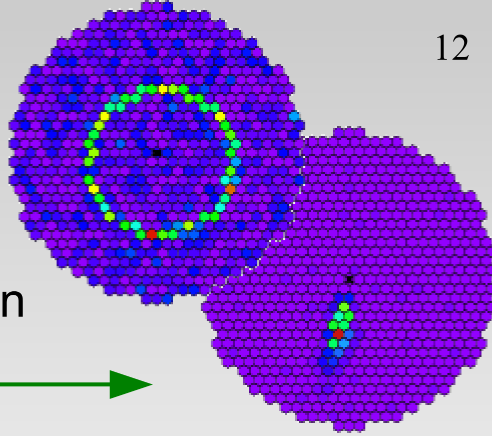

Trigger layout

- Possible layouts
    - 3NN coincidence
    - 4NN coincidence
    - ...
    - Sum of small clusters (3, 4, 5, ...)
    - Sum of large clusters continous 100
    - Sum of larger nested clusters
        - Advantage: small showers can trigger
        - Advantage: only a few thressholds to set